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Investigation on the Effect of Increasing Water Insufficiency on the Productivity and the Physical Grain Properties of Common Winter Wheat Cultivars

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Abstract

The trial was carried out in a specially constructed greenhouse. During the period of investigation (2011 – 2013), the experiment involved 11 common wheat cultivars in 4 replications. The cultivars were grown on Haplic Chernozems under two regimes of water supply – optimal (OWS) and increasing water insufficiency, or water deficit (WD) till the end of the growing season. The water regimes were imitated by watering and maintenance of 80-85 % of MSMA (marginal soil moisture absorption) and by causing of drought at 45-50 % MSMA. Under the optimal water regime, cultivars Bojana, Bolyarka, Rada and Bezostaya 1 formed maximal total shoot biomass. The water insufficiency sharply decreased the productivity of the cultivars with a mean of 35.52 % in comparison to the optimal water regime. Highest total shoot biomass was measured in cultivars Yantur, Bojana and Rada. Under both regimes of water supply, cultivars Bojana, Bolyarka, Lazarka, Rada and Yantur had highest productivity. The increasing water insufficiency during the growing season of the crop caused lower amplitudes in the variation of the investigated indices in cultivar Lazarka as compared to all other cultivars. This cultivar had the highest harvest index under severe drought. The working efficiency of a vegetation mass unit regardless of the water supply was highest in cultivar Bolyarka. Under severe water insufficiency the same was valid for cultivars Lazarka, Neda, Slaveya and Yantur. The water insufficiency contributed to the decrease of the absolute weight of the grain with 28.3 % and caused significant variation of the values depending on the cultivar. Cultivars Bojana, Bezostaya 1, Bolyarka, Dragana and Lazarka were significantly less affected by the severe insufficiency of soil moisture and possessed larger grain than the rest of the cultivars. Under optimal water supply in the course of the growing season, cultivar Bolyarka had the largest grain. This tendency was valid in all three years of the experiment, the differences with the other cultivars being within the range 5 – 19.9 g.

Key words: Wheat, Cultivars, Drought stress, Yield components, Physical grain properties, Correlation

Introduction

Drought is a polygenic stress and is considered as one of the most important factors limiting crop yields around the world. As climate change leads to increasingly hotter and drier summers, the importance of drought constraints on yield and yield components has increased in the world. The ability of a cultivar to produce high and satisfactory yield over a wide range of stress and non-stress environments is very important (Kilic and Yagbasanlar, 2010; Johari-Pireivatlou and Maralian, 2011; Montazar and Azadegan, 2012). The response of plants to water stress depends on several factors such as developmental stage, severity and duration of stress and cultivar genetics (Duan et al, 2008; Li et al, 2011; Khakwani et al, 2012).

All stages of crop growth are not uniformly susceptible to water scarcity. On the other hand, some stages can cope-up with water shortage very well, while others are more susceptible and water shortages at such stages may result in distinct yield losses. Moisture stress is known to reduce biomass, tillering ability, grains per spike and grain size at any stage when it occurs. So, the overall effect of moisture stress depends on intensity and length of stress (Akram, 2011; Kharel et al, 2011; Jäger et al, 2014).

Wheat (*Triticum aestivum* L.) is an important crop in Bulgaria, where high temperatures and water stress often reduce plant growth and crop yields. Therefore, wheat yield is lowered. Wheat production in Bulgaria has always been related to the necessity of tolerance to abiotic stress. The annual meteorological anomalies present constant challenge to winter wheat breeding (Tsenov and Penchev, 1995; Tsenov et al, 2006; Tsenov et al, 2008[a, b]). The higher cold and drought tolerance, the lower production losses will be in the future. One of the practical possibilities to do this is to carry out breeding for increasing grain yield by increasing tolerance to abiotic stress (Vassileva et al, 2011; Ivanova and Tsenov, 2011; Tsenov et al, 2012; Tsenov et al, 2013).

The role of the cultivar depending on the level of different agronomy practices can vary from 8 to 15 %, or even 20 %. Under abiotic stress, the effect of the factor cultivar can be significantly higher (Tsenov, 2006).

The aim of this investigation was to study the effect of long-term and increasing water stress during the growth season of various *Triticum aestivum* L. cultivars on their productivity and physical properties of grain.

Material and Methods

The investigation was carried out during 2011 – 2013 in a rain-out shelter constructed for simulation of drought at the Laboratory complex of Dobrudzha Agricultural Institute – General Toshevo. The soil in the trial area was slightly leached chernozem (Haplic Chernozems –WRBSR, 2006).

The tolerance of wheat to long drought was tested in two variants: 1) optimal regime of water supply (OWS) during the entire growing season by maintaining 80-85 % of marginal soil moisture absorption (MSMA); 2) Increasing water deficiency (WD) till the end of the growing season by maintaining 45 – 50 % of MSMA. Before sowing, the experimental area was equalized by soil moisture reserves in the 0-60 cm layer. The determined initial soil moisture for both variants prior to sowing was averagely 21.93 %.

Table1. Soil moisture after harvesting, %

Depth, cm	OWS	WD
0-20	11.05	7.44
20-40	13.02	8.68
40-60	15.42	8.47

During the growing season of wheat, in the variant with OWS, watering was applied two or three times, the last of which after heading-flowering. In the variant with increasing water deficiency, no water supply was available till the end of the growing season. Soil moisture, expressed as percent of its absolute dry weight after harvesting of wheat, varied significantly down the soil profile under both water regimes (Table 1).

In the variant with optimal water supply, the soil moisture determined after harvesting was averagely 60.0 % from the initial one, and in the variant with increasing water deficiency it was 37.4 %.

Eleven common winter wheat (*Triticum aestivum* L.) cultivars were tested, including 10 Bulgarian varieties and the Russian cultivar Bezostaya 1 (Table 2).

The agro chemical analyses carried out to characterize the experimental area and to determine soil moisture were done in 4 replications at both plots where soil moisture regimes were imitated (Table 3). The analysis on the mobile forms of the main macro elements showed that optimal nutrition regime was ensured.

Table2. Characteristics of the tested wheat varieties

No	Varieties	Origin	Year	Pedigree
1	Bojana	Bulgaria	2010	Obrij / Milena
2	Bolyarka	Bulgaria	2004	Pryaspa / F 2076 W2-11
3	Dragana	Bulgaria	2009	Miryana / Nadia
4	Lazarka	Bulgaria	2007	Una /Flamura 85
5	Neda	Bulgaria	2004	GP 2558-128 //Sadovo 1/Roason
6	Rada	Bulgaria	2012	Enola / Preslav
7	Slaveya	Bulgaria	2001	GP 2558-128/2 x Pliska
8	Stoyana	Bulgaria	2010	2477-2 / Slaveya
9	Yantur	Bulgaria	1983	Aurora / Era
10	Bezostaya 1	Russia	1955	Skorospelka 2 / Lut. 17
11	Dobrudzhanka	Bulgaria	1996	Pliska / 2* Albidum 114

Table3. Agro chemical analysis of the trial area prior to sowing of wheat

Water regime	Depth, cm	pH H_2O	pH KCl	NH_4	NO_3	Summ	P_2O_5	K_2O
				mg/1000 g soil			mg/100 g soil	
OWS	0-20	6,74	8,12	2,98	31,26	34,24	17,56	22,64
WD	0-20	7,21	8,08	4,35	36,11	40,46	24,31	24,81
OWS	20-40	6,73	8,16	3,01	17,99	21,00	8,48	22,19
WD	20-40	7,17	8,11	2,58	13,47	16,04	7,21	22,19
OWS	40-60	6,89	8,11	2,15	16,13	18,28	3,86	20,65
WD	40-60	7,06	7,92	2,48	30,91	33,39	3,97	20,68

The analysis of the variances of the investigated productivity characteristics of the tested wheat cultivars in the variant with optimal water supply showed maximal level of statistical significance of the factors year and cultivar (Table 4). Similar tendency was observed in the variant with increasing soil moisture deficiency till the end of the growth season, which was not valid only for the non-grain part of the spike with regard to the effect of the investigated years. The genotype as a factor, however, maintained a high effect on this plant organ marked with a high level of significance.

The interaction of the two factors under both regimes of water supply undoubtedly had significant effect of the formed biomass of leaves and stems, as well as on the grain size. Under optimal water supply, the effect of the combined interaction of the factors on the formed vegetative and total shoot biomass and on the non-grain part of the spike was significant. Under conditions of long and increasing water deficit, the interaction of the factors in the other indices was not significant.

Table4. Analysis of the variances of the shoot biomass formed by plant organs

Source	Dependent Variable	df	OWS F	OWS *p-value*	WD F	WD *p-value*
Years	Leaves	2	180,756	,000	23,601	,000
	Stems	2	51,776	,000	11,456	,000
	Spikes	2	13,343	,000	4,394	,000
	Grain	2	11,555	,000	5,410	,000
	Non-grain part of spikes	2	15,848	,000	1,971	,044^{NS}
	V. mass	2	68,042	,000	6,766	,000
	T. mass	2	19,824	,000	6,960	,000
	OneVmGrain	2	37,453	,000	3,706	,000
	GHI	2	35,670	,000	3,616	,000
	1000 grain weight	2	353,913	,000	366,429	,000
Genotypes	Leaves	10	32,859	,000	479,027	,000
	Stems	10	28,417	,000	234,660	,000
	Spikes	10	6,647	,000	120,488	,000
	Grain	10	6,027	,000	134,200	,000
	Non-grain part of spikes	10	9,868	,000	12,982	,000
	V. mass	10	27,826	,000	175,368	,000
	T. mass	10	11,536	,000	210,021	,000
	OneVmGrain	10	5,374	,000	18,035	,000
	GHI	10	4,388	,000	16,177	,000
	1000 grain weight	10	296,571	,000	1602,096	,000
Years * Genotypes	Leaves	20	2,862	,000	2,635	,001
	Stems	20	4,223	,000	2,617	,001
	Spikes	20	1,624	,062^{NS}	1,247	,234^{NS}
	Grain	20	1,499	,099^{NS}	1,861	,024^{NS}
	Non-grain part of spikes	20	2,018	,012	,943	,535^{NS}
	V. mass	20	4,234	,000	1,357	,163^{NS}
	T. mass	20	2,348	,003	1,760	,036^{NS}
	OneVmGrain	20	,950	,528^{NS}	,999	,470^{NS}
	GHI	20	,831	,671^{NS}	1,012	,456^{NS}
	1000 grain weight	20	19,291	,000	61,441	,000

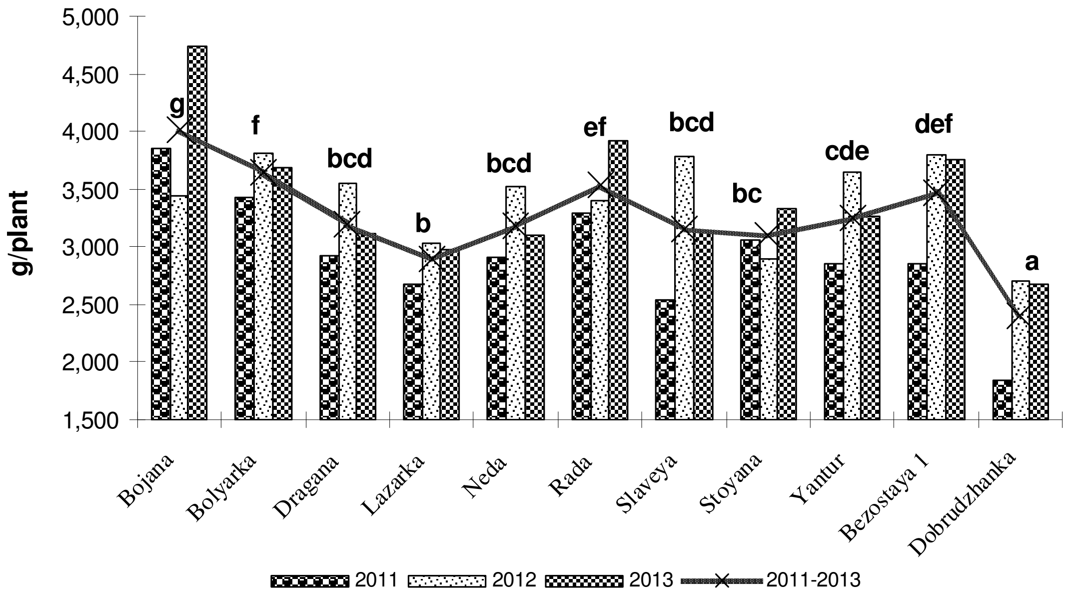

Figure1. Total shoot biomass per plant at OWS in soil, g (Waller-Duncan N=12)

The obtained results showed significant variation of the cultivars' productive potential over years (Figure 1). Regardless of some variations in the total productivity per spike-bearing plant, it was found that under conditions of OWS during vegetation, cultivar Bojana had highest mean total shoot biomass (4.013 g), exceeding the mean productivity of the group with 23.2 %.

To some extent cultivars Bolyarka and Rada were characterized with similar powerful development of the total formed shoot biomass at technical maturity stage. Cultivars Dobrudzhanka, Lazarka, Stoyana, Slaveya and Dragana formed shoot mass below the mean value of the group. A marked peculiarity of cultivar Lazarka was the formation of total shoot biomass yield with lowest amplitude of variation over years. The Waller-Duncan test redistributed the obtained mean yields into 7 groups, cultivars Bojana and Dobrudzhanka markedly standing out. In all other genotypes close or more distant similarity in the response to the tested conditions of the trial field was found.

In the variant with increasing water deficiency till the end of the growing season, the mean formed total shoot biomass was 2.100 g, which was 64.48 % from the biomass formed under optimal available soil moisture reserves (Figure 2). This means that the mean decrease of the total formed shoot biomass as a result from increasing water stress was with 35.52 %. Cultivars Bojana and Yantur had higher mean values of total shoot biomass, averaged for the period, and fell into groups “d” and “cd”, respectively. Their exceeding above the mean values of the groups was with 17.74 % and 12.63 %, respectively. In cultivars Bezostaya 1, Stoyana, Slaveya and Dobrudzhanka the formed mean yield of total biomass was below the mean yield of the group of cultivars and was 96.38 %, 94.61 %, 93.95 % and 74.47 % from it, respectively.

The Waller-Duncan test distinguished the obtained results for the total shoot biomass formed during the years of investigation (Table 5). Under regime of optimal water supply (OWS), the differentiation in the values of the index was less expressed in comparison to variants with increasing water stress during the growing season.

Table5. Effect of the year conditions of investigation on the total formed shoot biomass of wheat

Years (Waller-Duncan N=44)	T. mass	
	OWS	WD
2011	2,927 a	2,306 b
2012	3,417 b	1,352 a
2013	3,427 b	2,643 c

In the organs forming the vegetative mass there was a significant differentiation in the values of the formed dry matter depending on the genotype and the water regime applied during the growing season (Table 6). The highest percent of the vegetative mass belonged to the stems; in all cultivars decrease of the stem biomass was observed under severe drought. Averaged for the group of tested cultivars, this decrease was with 28.84 % in comparison to the regime with optimal water supply. Under drought, most significant decrease of the stem biomass was found in cultivars Bojana and Bolyarka; their stem mass was 63.86 % from the mass formed under OWS regime. Two of the tested cultivars had lowest dry matter loss from the stems – Yantur and Lazarka; their stem mass under WD regime was 82.20 % and 80.67 %, respectively, from the mass formed under OWS regime.

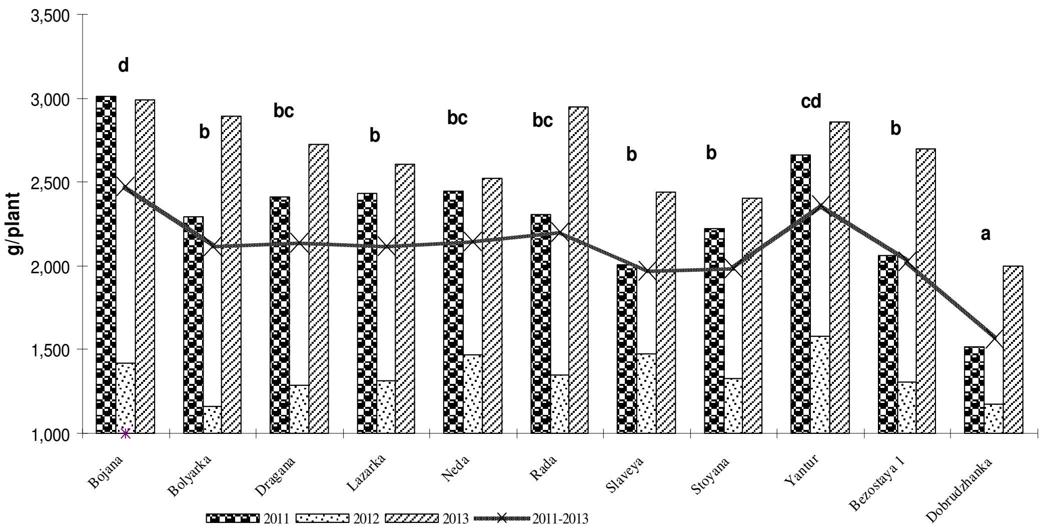

Figure2. Total shoot biomass per plant under increasing water deficit (WD), g (Waller- Duncan N=12)

Table6. Effect of the water supply regime on dry matter by organs of vegetative mass per plant, g

Genotypes	Leaves		Stems		Non-grain part of spikes	
(Waller-Duncan N=12)	OWS	WD	OWS	WD	OWS	WD
Bojana	,519 f	,443 g	1,200 g	,767 g	,400 fg	,248 a
Bolyarka	,389 e	,341 bc	,974 e	,622 cde	,372 def	,249 a
Dragana	,368 cde	,367 de	,742 a	,553 ab	,412 g	,382 b
Lazarka	,313 b	,354 cd	,755 ab	,609 bcd	,338 cd	,237 a
Neda	,357 cd	,393 f	,818 bc	,623 cde	,334 bc	,245 a
Rada	,377 de	,390 ef	,983 ef	,677 ef	,397 fg	,310 ab
Slaveya	,347 c	,354 cd	,826 c	,576 bc	,378 efg	,242 a
Stoyana	,304 ab	,325 b	,896 d	,665 def	,298 ab	,213 a
Yantur	,391 e	,438 g	,841 cd	,691 f	,345 cde	,253 ab
Bezostaya 1	,380 de	,366 cde	1,051 f	,692 f	,382 fg	,268 ab
Dobrudzhanka	,284 a	,268 a	,717 a	,498 a	,272 a	,185 a

Similar tendency was observed for the non-grain part of the spike as well. The mean dry matter loss according to the OWS variant was with 28 %. Cultivars Dobrudzhanka, Bolyarka, Slaveya and Bozhana had mean loss from 32 % to 38 %. The dry matter loss from the non-grain part of the spike was lowest in cultivar Dragana – only 7.2 %.

An interesting tendency was noted in the response of the cultivars with regard to the changes in the dry matter of the leaf mass at the end of the growing season. Averaged for the period of investigation and the tested cultivars, significant variations in the leaf mass formed per plant under both tested water supply regimes (OWS – 0.366 g and WD – 0.367 g) were not observed. In all three years of the investigation, cultivars Bojana and Bolyarka had highest dry matter loss from their leaf mass under drought, which amounted to about 14 %. Similar tendency was observed in cultivars Bezostaya 1 and Dobrudzhanka but their loss was between 2.7 % and 3.8 %. In the other cultivars, the leaf mass maintained the same dry matter weight, and in the case of cultivars Lazarka and Yantur it was even higher.

Finally, the vegetative biomass formed in the variants with increasing water deficiency at technical maturity of plants was 73.40 % from the biomass formed in the OWS variants. The differentiation between the cultivars was well expressed; under both water regimes the obtained vegetative mass yields were distributed into 5 groups according to the Waller-Duncan test (Figure 3). Cultivar Bojanka ("e") had highest values of the vegetative biomass formed per plant under both water regimes, while cultivar Dobrudzhanka ("a") had the lowest.

Under OWS regime, the differences were clearly defined, as well as the sameness of the cultivars' response at significantly less expressed similarity. In the variant with increasing water deficit only the response of cultivars Bojana and Dobrudzhanka was clearly differentiated. All other cultivars were characterized with significantly higher similarity in their response to the moisture deficiency in soil.

Under regime of optimal available moisture reserves in soil (OWS) all tested cultivars formed grain yield per spike above 1 g. The variation of productivity was from 1.135 g (Dobrudzhanka) to 1.912 g (Bolyarka) (Figure 4). Cultivars Bozhana and Rada also had high grain yield. The mean productivity of the tested cultivars was 1.643 g grain per spike.

In the variants with increasing water deficit the mean productivity of the cultivars was 0.842 g. This mean yield was 51.25 % from the yield obtained under optimal water supply of the plants. Averaged for the investigated period, grain yield per spike varied within a rather wide range: from 0.613 g in cultivar Dobrudzhanka to 1.016 g in cultivar Bojana. Cultivars Yantur, Lazarka and Bolyarka were close to a maximum degree to cultivar Bojana by their grain yield per spike.

Cultivar Lazarka had much lower amplitude of variation of the values of the total formed shoot biomass and grain between the two water supply variants in comparison to the other cultivars (Figure 5).

The working efficiency of a vegetative mass unit varied significantly in the individual cultivars depending on the water supply variant (Table 7). In the variant with optimal water supply, a vegetative mass unit produced grain above 1 g, with the exception of cultivars Dobzudzhanka, Bojana and Bezostaya 1, which fell within the group of lowest order. Highest values, averaged for the period, were determined in cultivar Neda, followed by most of the tested cultivars, which were referred to group "cd".

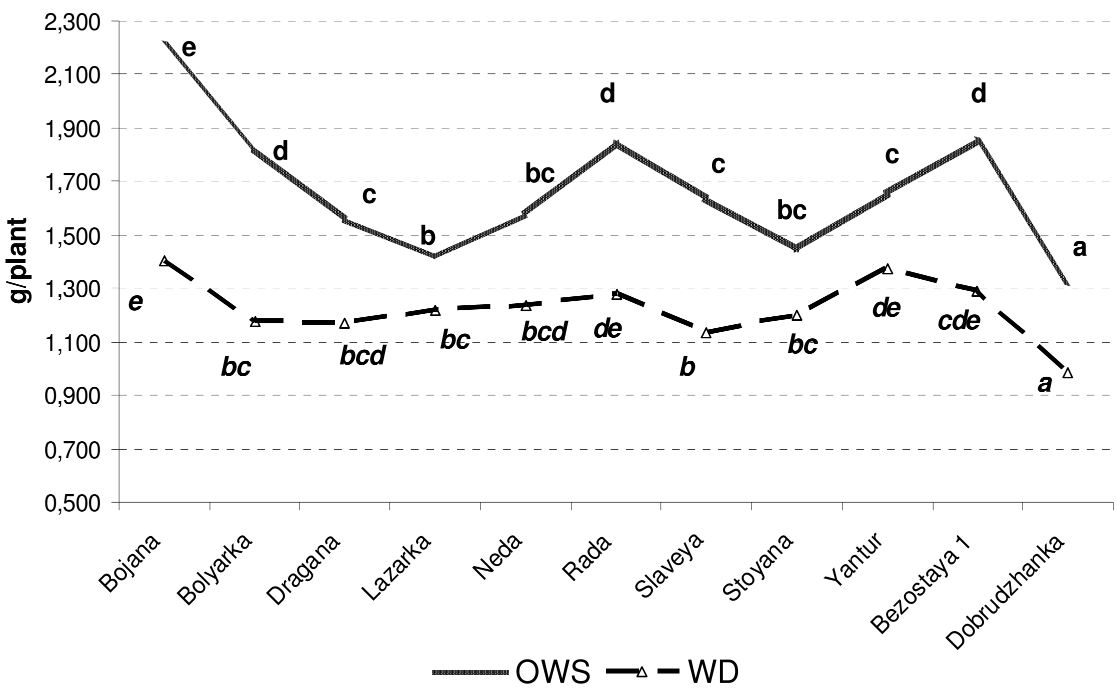

Figure 3. Vegetative biomass per plant depending on the water regime of soil, g (Waller-

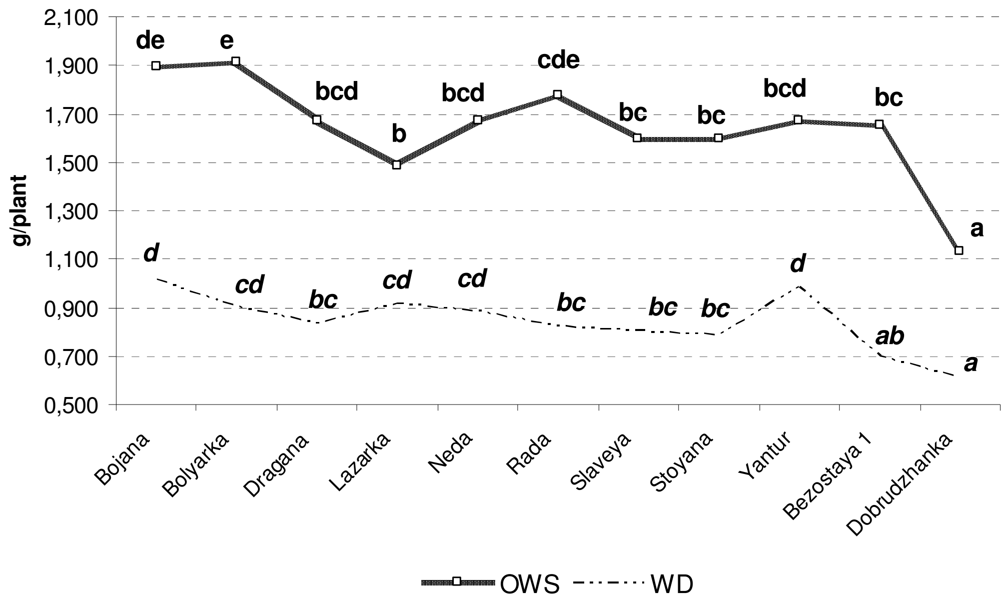

Figure4. Effect of the water supply regime on grain yield per spike, g (Waller-Duncan N=12)

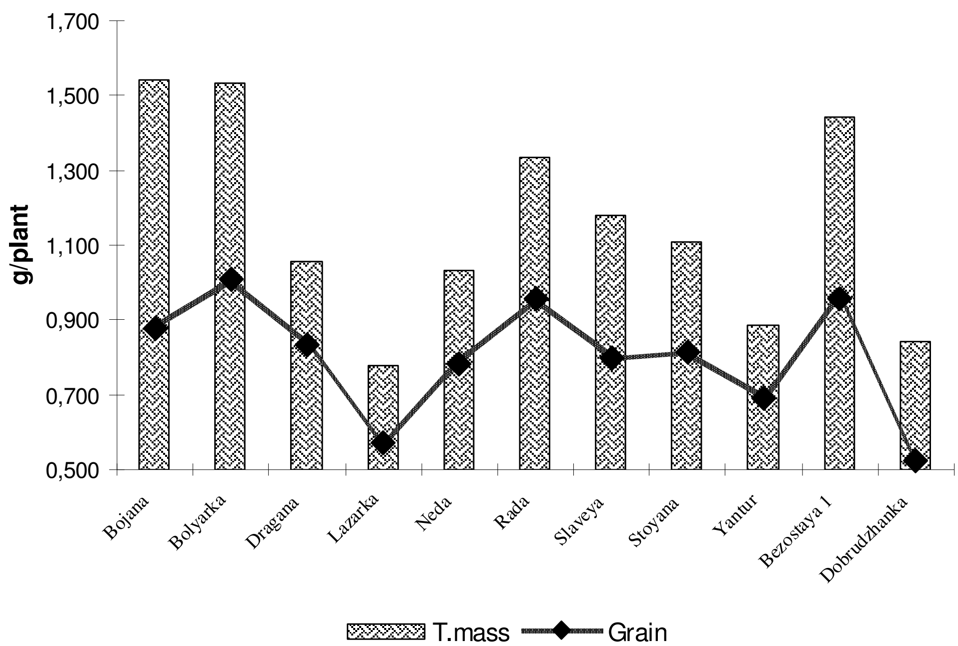

Figure5. Amplitude of variation of the formed total mass and grain yields between the two water supply variants, g/plant

The increasing water deficit during the growing season of the crop sharply decreased the productivity of a vegetative mass unit and averaged for the cultivars it was 64.34 % from the productivity determined under optimal water supply, i.e. there was a decrease with 35.7 %. Comparing in absolute values the results obtained in the variant with increasing water deficit, regardless of the decreased productivity, best results were obtained from cultivars Bolyarka and Lazarka, in which a vegetative mass unit produced from 0.710 to 0.743 g of grain.

Table7. Grain production per vegetative mass unit depending on the water supply regime.

Cultivars	OWS	WD	In % to OWS
Bojana	,904 a	,673 bcd	74,45
Bolyarka	1,101 cd	,710 cd	64,49
Dragana	1,102 cd	,649 bcd	58,89
Lazarka	1,061 cd	,743 d	70,03
Neda	1,112 d	,693 cd	62,32
Rada	1,013 bc	,598 ab	59,03
Slaveya	1,019 cd	,680 bcd	66,73
Stoyana	1,076 cd	,641 bc	59,57
Yantur	1,060 cd	,694 cd	65,47
Bezostaya 1	,916 ab	,514 a	56,11
Dobrudzhanka	,892 a	,630 bc	70,63
Mean	1,023	0,657	64,34

These results were clearly reflected in the data on the percent of vegetative biomass and its components according to the total shoot biomass formed (Table 8). The established differences at level cultivar became greater in the variant with increasing moisture deficit. On the whole, while productivity decreased under water deficiency, the percent of vegetative biomass increased.

This increase was with 21.6 %, averaged for the tested cultivars. In the respective components forming the vegetative mass, the increase for leaves was with 65.0 %, for stems – with 12.2 %, and for the non-grain part of spikes – with 11.8 %. These results showed that significant restructuring occurred in the percent of the respective organs ultimately responsible for the flow of assimilates to the grain. Among all cultivars, Bezostaya 1 had highest percent of the vegetative mass, especially in the variant with water deficit, which reflected on the values of the harvest index as well (Table 9).

Under optimal water regime of soil, the percent of grain in all cultivars was above 50 % from the total biomass formed, with the exception of cultivars Dobrudzhanka, Bezostaya 1 and Bojana. Highest harvest index, averaged for the period, was registered in cultivars Bolyarka, Dragana and Neda (0.52).

The artificial imitation of severe water stress reduced the percent of grain in the total biomass with 21.9 %. The genotypic differentiation was strongly expressed, the variation being from 33.38 % (Bezostaya 1) to 42.27 % (Lazarka). In all three years of the investigation, cultivar Lazarka ranked first by this index. This cultivar had lower values in the variation between the two variants of water supply by a number of other indices, as well, which was also reflected in the high grain yield per spike under increasing water deficit.

Absolute grain weight was also influenced by the water regime of soil besides by the type of cultivar (Table 10). Under optimal water regime cultivar Bolyarka had largest grain. Averaged for the three years of investigation, the values of this index were 62.00 g, followed by cultivars Dragana and Neda.

Under conditions of water deficit, the variation of the values was from 30.37 g to 41.84 and 41.89 g in the cultivars Dobrudzhanka, Bojana and Bezostaya, respectively. Cultivars Bolyarka, Dragana and Lazarka conceded to them with about 1 g in absolute values. Under both regimes of water supply, cultivar Dobrudzhanka had the smallest grain.

The established correlations between the separate organs of the shoot biomass demonstrated high statistical significance (Table 11).

Table8. Percent of vegetative mass organs from the total formed biomass, %

No	Cultivars	Vegetative biomass		Leaves		Stems		Non-grain part of spike	
		OWS	WD	OWS	WD	OWS	WD	OWS	WD
1	Bojana	53,02	60,41	12,92	18,43	29,78	31,23	10,05	10,33
2	Bolyarka	47,99	59,56	10,73	16,59	26,79	30,33	10,24	12,12
3	Dragana	47,97	61,23	11,79	17,72	23,30	26,78	12,89	16,61
4	Lazarka	49,17	57,73	10,98	17,02	26,30	29,24	11,74	11,47
5	Neda	47,83	59,29	11,43	18,28	25,86	29,33	10,56	11,65
6	Rada	49,91	61,37	10,74	17,63	27,90	31,37	11,29	14,02
7	Slaveya	49,22	59,47	11,26	17,87	26,54	29,34	12,03	12,42
8	Stoyana	48,28	61,50	9,76	16,41	28,89	33,93	9,75	10,90
9	Yantur	49,03	60,02	12,18	18,71	25,93	29,46	10,66	11,12
10	Bezostaya 1	52,71	65,16	10,99	18,56	30,21	34,73	11,10	13,44
11	Dobrudzhanka	53,73	61,92	11,96	17,43	29,82	32,14	11,41	12,09
	Mean	49,90	60,70	11,34	17,69	27,39	30,72	11,07	12,38

Table10. Absolute grain weight depending on the water regime, g (Waller-Duncan N=12)

Genotypes	1000 grain weight	
	OWS	WD
Bojana	50,43 c	41,84 f
Bolyarka	62,00 h	40,38 e
Dragana	56,90 g	40,69 e
Lazarka	51,24 d	40,77 e
Neda	56,93 g	35,39 b
Rada	54,62 f	36,28 c
Slaveya	51,76 d	36,29 c
Stoyana	47,41 b	35,12 b
Yantur	52,86 e	38,26 d
Bezostaya 1	56,29 g	41,89 f
Dobrudzhanka	41,81 a	30,37 a

This high significance considerably increased for leaves and stem under conditions of water stress. The correlation of grain yield with the organs producing the vegetative mass in both water supply variants was higher for stems than for leaves. A tendency was observed toward sharp increase of the correlation coefficient values expressing the relation in the grain-and-leaves apparatus under drought (r = .846**). The increase in comparison to the OWS variant was 2.3 times.

Grain yield was in well expressed significant correlation with the mass of the non-grain part of spike. It had high values under OWS, where r = .724**. In the variant with increasing water stress, regardless of the high statistical significance, the values of the correlation coefficient decreased almost 2 times (r = .350**).

Under both regimes of water supply, grain size was in high correlation with the biomass formed by organs and with the GHI. The values of the correlation coefficients significantly increased under water stress in comparison to OWS in all investigated correlations, with the exception of the correlation with the non-grain part of spike. Regardless of the decrease of the correlation coefficient values of absolute grain weight and the mass of the non-grain part of the spike, this coefficient had high statistical significance.

Table11. Correlations between some main characteristics of productivity according to the regime of water supply (Pearson Correlation)

Indices	Leaves		Stems		Glumes		V. mass	
	OWS	WD	OWS	WD	OWS	WD	OWS	WD
Leaves			,734**	,887**	,386**	,414**	,838**	,902**
Stems	,734**	,887**			,571**	,399**	,965**	,917**
Spikes	,383**	,839**	,703**	,863**	,796**	,641**	,725**	,929**
Grain	,365**	,846**	,696**	,881**	,724**	,350**	,700**	,828**
Non-grain part of spikes	,386**	,414**	,571**	,399**			,688**	,708**
V. mass	,838**	,902**	,965**	,917**	,688**	,708**		
T. mass	,632**	,916**	,889**	,942**	,767**	,564**	,909**	,961**
GHI	-,427**	,393**	-,099	,420**	,227**	-,111	-,139	,285**
1000 grain weight	,352**	,725**	,338**	,706**	,515**	,363**	,427**	,709**

Indices	Grain		T. mass		GHI		Mass of 1000	
	OWS	WD	OWS	WD	OWS	WD	OWS	WD
Leaves	,365**	,846**	,632**	,916**	-,427**	,393**	,352**	,725**
Stems	,696**	,881**	,889**	,942**	-,099	,420**	,338**	,706**
Spikes	,994**	,944**	,943**	,979**	,558**	,569**	,540**	,696**
Grain			,934**	,951**	,595**	,742**	,520**	,693**
Non-grain part of spikes	,724**	,350**	,767**	,564**	,227**	-,111	,515**	,363**
V.mass	,700**	,828**	,909**	,961**	-,139	,285**	,427**	,709**
T. mass	,934**	,951**			,278**	,523**	,517**	,734**
GHI	,595**	,742**	,278**	,523**			,216*	,317**
1000 grain weight	,520**	,693**	,517**	,734**	,216*	,317**		

* Correlation is significant at 0.05 level (2-tailed); ** Correlation is significant at 0.01 level (2-tailed).

Conclusions

Under optimal water regime, cultivars Bojana, Bolyarka, Rada and Bezostaya 1 formed maximum total shoot biomass. The water deficit sharply reduced the shoot biomass of the cultivars – with an average of 35.52 % according to the optimal water regime. Cultivars Yantur, Bojana and Rada were characterized with the highest total shoot biomass.

Under conditions of drought, the mass of stems decreased with 28.84 %, and of the non-grain part of spike – with 28.15 %, as compared to the optimal water supply regime. Significant differences in the mean leaf mass formed in the two water supply variants were not found, but the genotypic specificity remained the same. Cultivars Bojana and Bolyarka had lower values of dry matter in the leaf and stem mass. Regardless of this fact, however, under both water regimes cultivar Bojana maintained maximum amount of vegetative mass.

Cultivars Bolyarka and Bojana had high grain weight of spike under optimal water supply, and under conditions of increasing water stress till the end of the growing season these were cultivars Bojana and Yantur. The mean yield from the tested cultivars under increasing drought till the end of the growing season was 51.25 % from the yield obtained under optimal water supply, or the mean decrease of productivity was with 48.75 %.

The increasing water deficit caused the lowest amplitude in the variation of grain yield in cultivar Lazarka in comparison to the other cultivars. This cultivar had the highest harvest index under severe drought.

The working efficiency per vegetative mass unit regardless of the water supply was highest in cultivars Bolyarka and Dragana. Under severe water deficit this was valid for cultivar Lazarka as well, followed by cultivars Dragana and Yantur.

The water deficit contributed to 28.34 % lower grain weight and to considerable variation of the values depending on the cultivar. Under optimal water supply in the course of the vegetation, cultivar Bolyarka had largest grain followed by cultivars Neda, Dragana and Bezostaya 1. Under conditions of water stress, cultivars Bojana and Bezostaya 1 maintained the largest grain size, followed by cultivars Bolyarka, Lazarka and Dragana.

Cultivar Dobrudzhanka had the lowest values of all investigated indices under both regimes of water supply.

Significant correlations were found between the investigated elements of productivity; the values of the correlation coefficients significantly increased under water stress as compared to optimal water supply.

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